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GEOLOGY, ENERGY, AND MINERAL (GEM) RESOURCE ASSESSMENT OF THE BITTER CREEK GEM RESOURCE AREA (GRA), MONTANA, INCLUDING THE BITTER CREEK WILDERNESS STUDY AREA (MT-064-356)

PHASE I

Contract No. YA-553-CT2-1055

Prepared for:

U.S. Bureau of Land Management

Prepared by:

Tetra Tech, Inc.
Pasadena, California

August 1983

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EXECUTIVE SUMMARY

The U.S. Bureau of Land Management (BLM) has adopted a two-phase procedure for the integration of geologic, energy, and mineral (GEM) resources data concerning Wilderness Study Areas (WSAs). To facilitate this review, certain WSAs with similar geologic environments and mineral characteristics have been grouped together into larger GEM Resource Areas (GRA). Using these guidelines, the Bitter Creek WSA was grouped into the larger Bitter Creek GRA. This report, which terminates the Phase I activities for the Bitter Creek GRA, is an evaluation and interpretation of existing data concerning the GEM resource potential in the WSA.

The Bitter Creek GRA contains one WSA, the Bitter Creek WSA (MT-064-356). The Bitter Creek WSA is located in the BLM's Valley Resource Area, Lewistown District, Montana.

The Bitter Creek WSA has a low to high favorability for the potential occurrence of GEM resources. The WSA is considered to have low potential for the occurrence of uranium, sand, and gravel (classified 2B): this classification is based on indirect evidence. The WSA is considered to have low potential for geothermal resources (classified 2D); this classification is based on abundant direct and indirect evidence. The WSA is considered to have high potential for the occurrence of natural gas (classified 4D); this classification is based on abundant direct and indirect evidence. Finally, the area has a moderate potential for bentonite resources (classified 3C); this classification is based on direct but quantitatively minimal evidence.

The ocurrences of uranium and bentonite in the study area are associated with Bearpaw Shale (Geodata International, Inc., 1981; Berg, 1969). Natural gas and geothermal resources may be found at depth throughout the WSA associated with thin sandstones in Colorado Shale (Rice et al., 1980). Sand may be found in modern stream valleys and in glacial/fluvial deposits (Jensen and Varnes, 1964). Evidence for natural gas resources in the area is based on present production of this resource in the vicinity, and suitable geologic conditions expressed by the Bowdoin Dome. The geothermal evaluation of the area was

based on elevated temperatures (42°C) found at 3,200 feet and oil well logs. The uranium evaluation was based on radiometric anomalies related to parts of the Bearpaw Shale (Geodata International, Inc., 1981). Sand may be found in the same geologic environment as the aeolian deposits to the south of the study area.

Quantitatively minimal direct evidence exists to support a low favorability classification for the potential occurrence of other GEM resources in the WSA (classified 2C). This classification is based on the geologic environment and inferred geologic processes that have been identified within the WSA.

Additional geologic investigations would help supplement the GEM resource evaluation of the Bitter Creek GRA. A photogeologic study, supported by field checking, should be made to verify existing information. Additional understanding of the mineral resources of this area could be obtained by a review of the available literature listed as references in this report by BLM personnel.

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GEM RESOURCE AREA
BITTER CREEK

1.0 INTRODUCTION

1.1 Purpose of Study

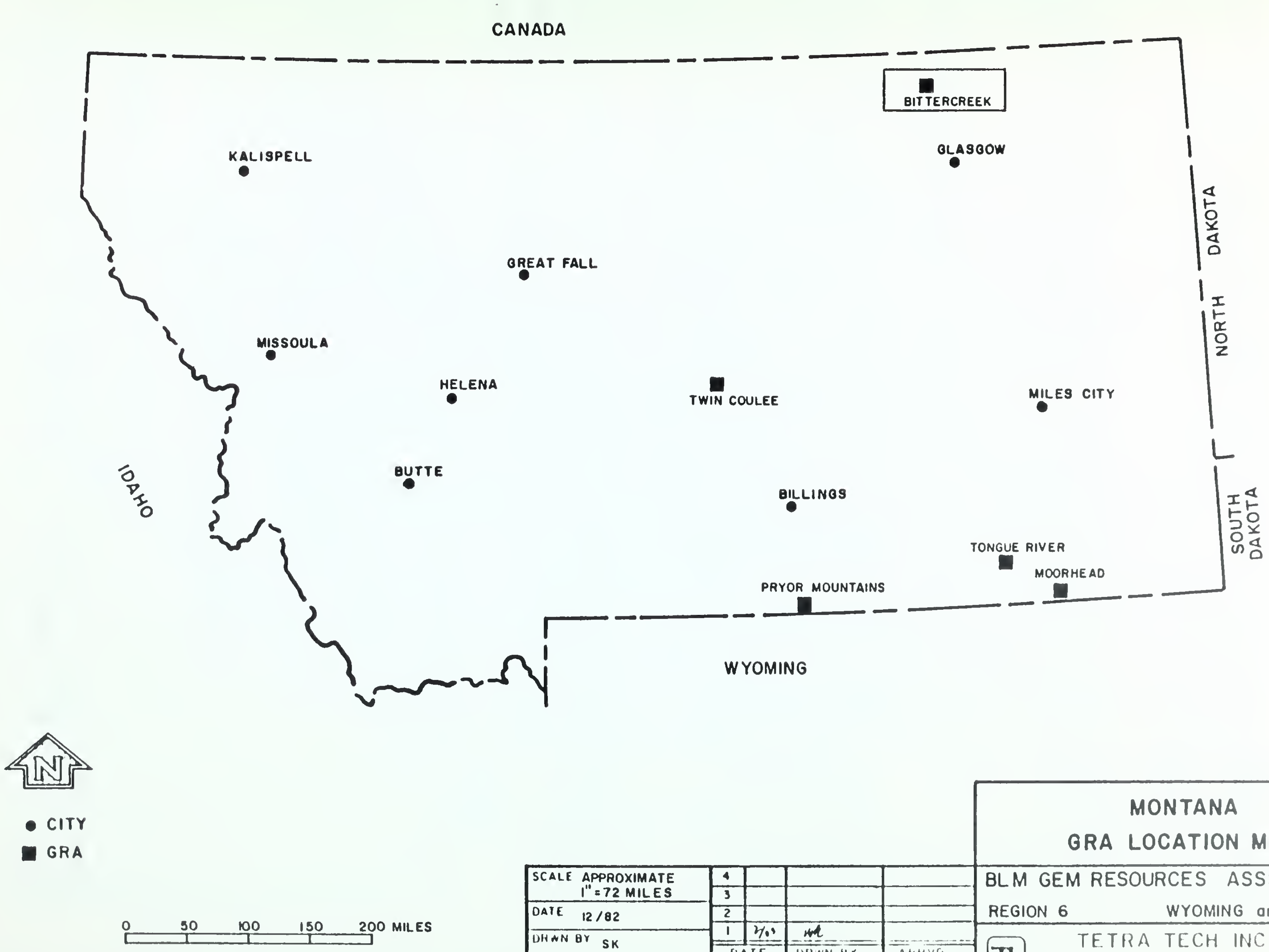
The U.S. Bureau of Land Management (BLM) has adopted a two-phase procedure for the integration of geologic, energy, and mineral (GEM) resources data for suitable/nonsuitable decisions concerning Wilderness Study Areas (WSAs). Phase I consists of a review and evaluation of existing data, resulting in an interpretation of the GEM resource potential of the WSAs. Phase II is designed to generate only the additional data required to support the GEM resource recommendations presented during Phase I. To facilitate this review, certain WSAs with similar geologic environments and mineral characteristics have been grouped together into larger GEM Resource Areas (GRA). Using these guidelines, the Bitter Creek WSA was grouped into the larger Bitter Creek GRA. This report, which terminates the Phase I activities for the Bitter Creek GRA, is an evaluation and interpretation of existing data concerning the GEM resource potential in the WSA.

The GEM resource evaluations for this study were performed by Tetra Tech, Inc. for the U.S. Bureau of Land Management, under Solicitation No. YA-553-CT2-1055. This study was completed in August, 1983.

1.2 Location and Access

The GEM report covers the area identified as the Bitter Creek GEM Resource Area (GRA); the geographic location of the study area is shown in Figure 1.1, "GRA Location Map."

The Bitter Creek GRA contains one WSA, the Bitter Creek WSA (MT-064-356). The Bitter Creek WSA consists of 59,112 acres and is located between 48°30' and 48°50' north latitude, and between 106°30' and 107° west longitude in parts of Township (T) 32-35 North (N), Range (R) 37-39 East (E), Prime Meridian, Valley



MONTANA
GRA LOCATION MAP

BLM GEM RESOURCES ASSESSMENT

REGION 6 WYOMING and MONTANA

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FIGURE 1.1

SCALE APPROXIMATE 1" = 72 MILES

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REVISIONS

County, Montana. The Bitter Creek WSA is located in the BLM's Valley Resource Area, Lewistown District, Montana. Figure 1.2, "Topographic Map," illustrates the topography of the GRA, as well as the location of the WSA within the GRA.

The Bitter Creek WSA is located 13 miles north of U.S. Route 2, at a point approximately 20 miles northwest of Glasgow, Montana. Access to the Bitter Creek WSA is by secondary gravel and unimproved dirt roads from U.S. Route 2.

1.3 Basis for Report

This report is based on an evaluation of existing data (both published and available unpublished data) collected from a variety of different sources. Some of the sources contacted during the preparation of this report include the U.S. Bureau of Land Management (BLM), the U.S. Geological Survey (USGS), the U.S. Bureau of Mines (USBM), the U.S. Department of Energy (DOE), the Wyoming Geological Survey, universities, and other sources.

The available literature was reviewed by a Project Team, assembled by the study contractor, comprised of authorities in the field of GEM resource evaluation. The members of the Project Team, and their associated technical disciplines, are identified below:

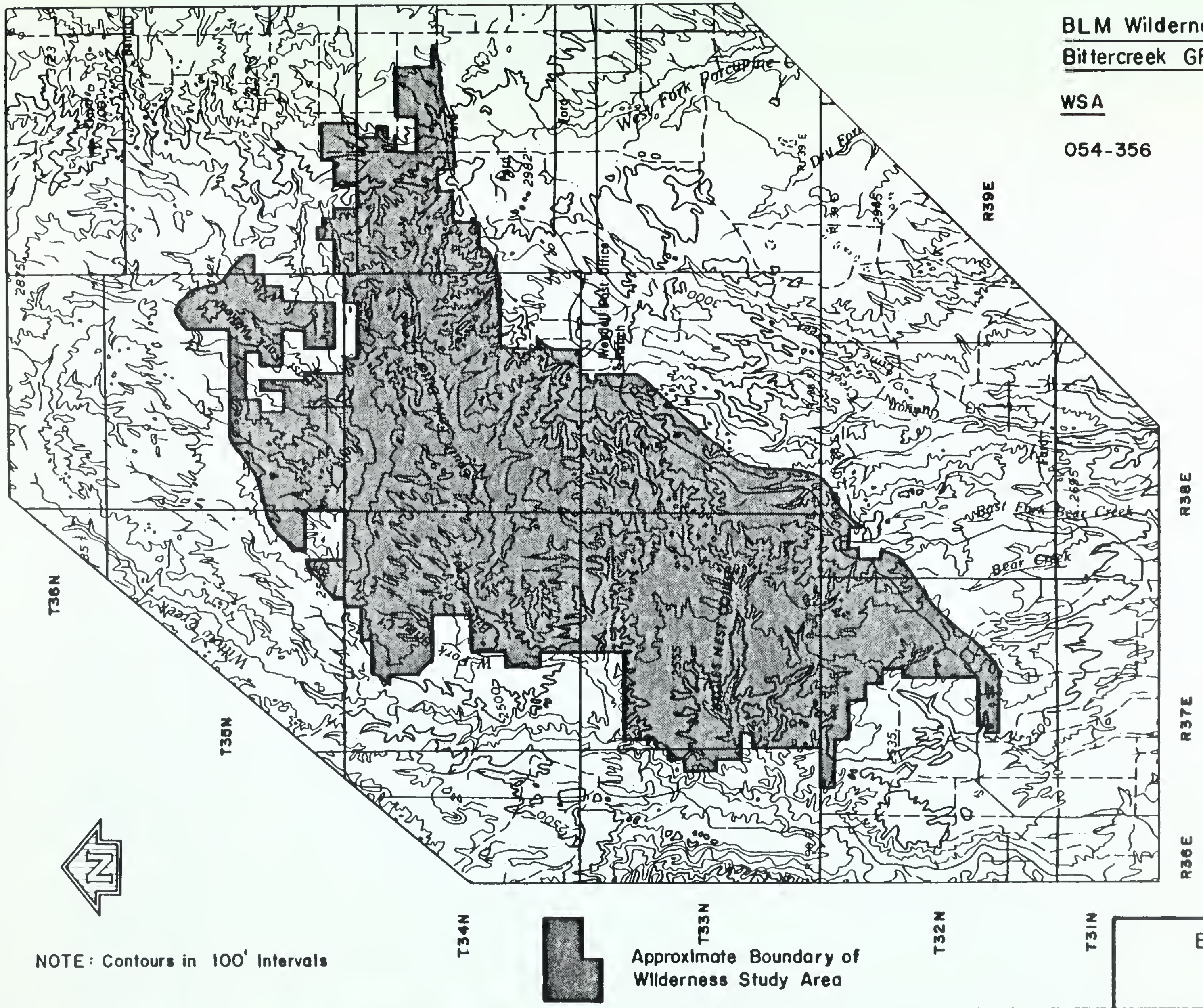
Mr. Charles S. Robinson	Metallic Minerals/Non-Metallic Minerals
Mr. Rollin E. Phipps	Oil and Gas
Mr. Andrew G. Alpha	Geothermal Resources
Mr. Stuart P. Hughes	Other Minerals
Mr. William A. Gallant	Other Minerals
Mr. Elmer M. Schell	Coal
Mr. John A. Hartley	Oil Shale/Paleontology

2.0 GEOLOGY

The geology of the Bitter Creek GRA is illustrated on the Montana State Geologic Map (Ross et al., 1955), and on the Glasgow 1° x 2° quadrangle

BLM Wilderness Study Areas Included in the Bittercreek GRA

WSA	NAME	ACREAGE
054-356	Bittercreek	59,112



NOTE: Contours in 100' Intervals

(USGS, 1954; limited revision, 1966)

Bittercreek GRA, Montana

TOPOGRAPHIC MAP

SCALE: 1" = 4 MILES 1:250,000	4			
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BLM GEM RESOURCES ASSESSMENT
REGION 6 WYOMING and MONTANA

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FIGURE 1.2

(International Exploration, 1980). Detailed geologic mapping has not been done within the Bitter Creek WSA. Available geologic maps, together with other sources of information listed in the references and bibliography of this report, form the basis for certain conclusions regarding GEM resources in the study area.

2.1 General

The Bitter Creek WSA is situated on the northeast flank of the Bowdoin Dome, on the west flank of the Opheim syncline. A thick sequence of sedimentary rocks underlie the WSA; these sedimentary rocks consist of rocks from Precambrian (> 600 million years before present [m.y.B.P.]) to Tertiary (35 m.y.B.P.) age. Upper Cretaceous (70-135 m.y.B.P.) Bearpaw Shale, Judith River and Fox Hills Formations, and the Tertiary (2-70 m.y.B.P.) Flaxville Formation crop out within the Bitter Creek WSA. Surficial deposits overlie the bedrock units and consist of glacial, alluvial, and colluvial materials.

2.2 Physiography

The Bitter Creek WSA is located in the glaciated Missouri plateau section of the Great Plains physiographic province. Elevations within the WSA range from 2,500 feet in the southern part of the area to 3,000 feet in the northern part. The drainage net consists primarily of intermittent tributaries of Bitter Creek. Bitter Creek drains the area to the south into the Milk River in the vicinity of Hinsdale, Montana. The climate of the study area is similar to other areas of northern Montana in that most precipitation occurs as snow during the winter months, with infrequent scattered rain showers during other times of the year.

2.3 Geologic Units

The geologic units that underlie the Bitter Creek WSA include rocks from Precambrian through Tertiary age. Several of the units that underlie the WSA are gas producers in the Bowdoin Dome area to the southwest; this gas comes from sandy zones in the Colorado Shale of lower to upper Cretaceous age in

particular. Surficial deposits overlie the bedrock units and consist of alluvial (Flaxville Formation), colluvial, and glacial deposits. Figure 2.1, "Geologic Map," delineates the geologic formations that crop out within the GRA. Figure 2.2, "Generalized Stratigraphic Column," is a generalized stratigraphic column which gives a brief description of all the stratigraphic units that underlie the Bitter Creek GRA.

2.3.1 Bedrock Units

The bedrock units that crop out within the Bitter Creek WSA are the Flaxville Formation of Tertiary age and the Bearpaw Shale and Judith River Formations of Upper Cretaceous age. The Flaxville Formation consists of brown, yellow, and gray gravel, sand and silt with volcanic ash. The Bearpaw Shale consists of dark olive, gray clayey shale with marine fossils with bentonite. The Bearpaw Shale overlies the Judith River Formation; the Judith River Formation consists of approximately 400 feet of light colored sandstone and greenish fissile shale. All of the older formations are illustrated on the generalized stratigraphic section. Specific descriptions of the units underlying the Judith River Formation would require an examination of oil well logs of the area; however, these units are briefly described in Figure 2.2.

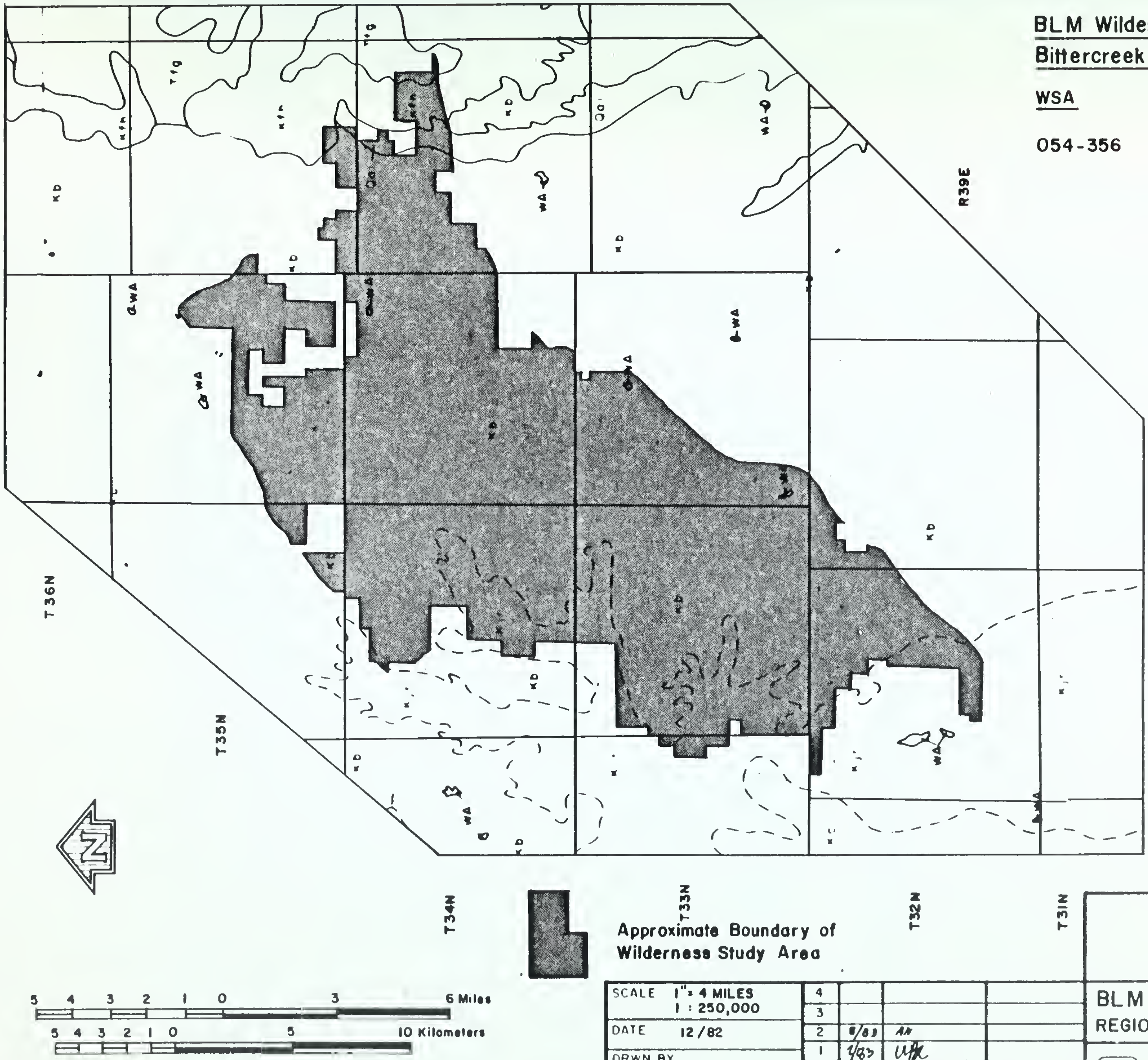
2.3.2 Surficial Deposits

Alluvial, colluvial, and glacial deposits overlie older sedimentary rocks in areas within the Bitter Creek WSA. The surficial deposits are generally thin (< 50 feet) and discontinuous. Alluvial deposits consist of alluvium and slope wash deposits. Alluvium is deposited along streams and consists of material eroded from local sedimentary strata. Slope wash deposits occur on gentle to moderate slopes above stream networks; these slope wash deposits were formed by erosion of sedimentary strata and other material by predominantly sheet wash processes.

Colluvium includes soil creep, landslides, and aeolian deposits. Soil creep occurs on slight to moderate slopes where colluvium, soil, and other materials slowly move downslope under the force of gravity. Landslides

BLM Wilderness Study Areas Included in the Bittercreek GRA

WSA	NAME	ACREAGE
054-356	Bittercreek	59,112



NOTE: WA Indicates Water

(International Exploration, 1980)

Bittercreek GRA, Montana

GEOLOGIC MAP

BLM GEM RESOURCES ASSESSMENT
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PASADENA, CALIFORNIA

FIGURE 2.1

SCALE	1" = 4 MILES 1 : 250,000
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SYSTEM	SERIES	SYMBOL	FORMATION	GENERAL LITHOLOGIC DESCRIPTION
QUATERNARY		Qa	Alluvium	
TERTIARY		Tfg	Flaxville	Alluvial and glacial clay, sand, and gravel
CRETACEOUS	UPPER	Kfh	Fox Hills	Sandstone; conglomerate
		Kb	Bearpaw Shale	Shale; shale and sandstone; conglomerate
		Kjr	Judith River	Shale; shale and sandstone; sandstone interbedded with shale; conglomerate
		Kcl	Claggett	Shale; shale and sandstone; conglomerate
		Ke	Eagle	Shale; sandstone; conglomerate
		COLORADO SHALE Kul	Telegraph Creek	Shale
			Niobrara	Shale; shale interbedded with limestone
			Carlile	Shale; sandstone and shale
			Greenhorn	Shale; limestone
			Belle Fourche	Shale; sandstone
	LOWER	Kl	Mowry	Shale
			Thermopolis	Shale
		KJ	Dakota	Sandstone; sandstone and shale
			Fuson	Sandstone interbedded with shale; shale
			Lakota	Sandstone; sandstone interbedded with shale
JURASSIC	UPPER		Morrison	Shale and sandstone
			Swift	Sandstone; sandstone and shale; sandstone interbedded with limestone
			Sundance	Shale; sandstone; limestone
	LOWER		Piper	Shale; sandstone; shale and sandstone
TRIASSIC		Ћ	Chugwater	Limestone; shale and sandstone; anhydrite
			Dinwoody	Shale; sandstone; anhydrite
PERMIAN		PM	Phosphoria	Chert; limestone; shale and sandstone; sandstone and anhydrite
PENNSYLVANIAN			Tensleep	Sandstone
			Amsden	Limestone and sandstone
			Tyler	Sandstone; sandstone and shale; anhydritic sandstone
MISSISSIPPIAN			Heath	Shale
			Otter	Anhydritic shale
			Kibbey	Sandstone
			Charles	Anhydritic limestone
			Mission Canyon	Limestone
			Lodgepole	Limestone
DEVONIAN		DЄ	Bakken	Sandstone; sandstone and shale
			Three Forks	Dolomite; limestone; sandstone
			Bird Bear	Limestone
			Duperow	Limestone; anhydrite
			Souris River	Dolomite; sandstone; anhydrite
SILURIAN			Interlake	Dolomite
ORDOVICIAN			Bighorn	Dolomite interbedded with shale
CAMBRIAN			Emerson	Limestone; shale; sandstone
PRECAMBRIAN		$p\epsilon_3$		Quartzite and metamorphic
		$p\epsilon_1$		Metamorphic and granite

Figure 2.2 Generalized Stratigraphic Column
Bitter Creek GRA

occur in areas of moderate to steep colluvial and bedrock slope, and in colluvium which consists of bedrock that has weathered in place on relatively flat slopes. Sand gravel deposits (glacial) probably occur on the ridge tops as a result of continental glaciation of the area (Colton, 1964A; Jensen and Varnes, 1964).

2.4 Structural Geology

Bedrock units that underlie the Bitter Creek WSA dip gently to the northeast off Bowdoin Dome, a Laramide (approximately 35 m.y.B.P.) structure. Details of the geologic structure of the area are basically unknown. The accumulation of gas occurs in thin sandstones of the Colorado Shale within the Bowdoin Dome area to the south and southwest (Rice et al., 1980).

2.5 Engineering Geology

The engineering geology of the area is concerned with bedrock and surficial deposits. The soil and rock derived from the Bearpaw Shale contains bentonite and has a high shrink-swell potential. Landslides and soil creep are also common in areas of Bearpaw Shale. Flash flooding is probably common during the short term intense rainfall that commonly occurs in the area.

2.6 Paleontologic Resources

No known vertebrate fossil localities are within the Bitter Creek WSA. Rare invertebrate fossils are used to define faunal zones within the Bearpaw Shale, which is marine in origin. Rare vertebrate fossils (mosasaurs) have been found in the Bearpaw Shale (Perry, 1962) and in the Judith River Formation (Kuhns, 1983). None of the vertebrate or vertebrate fossil localities have been identified within the WSA.

2.7 Historical Geology

The geologic history of the Bitter Creek area is similar to that of the Great Plains. The basement Precambrian rock units consist of metaigneous and

metasedimentary rocks, the history of which is not well understood. At the end of Precambrian time and throughout the Paleozoic (225 m.y.B.P.) era, there were repeated advances and retreats of the sea. Marine deposits of sandstone, shale and limestone were formed. During the deposition of the Paleozoic sediments, stratigraphic traps for hydrocarbons may have developed along facies changes, unconformities, and lithologic boundaries. At the end of the Paleozoic era, marine, marginal marine (evaporites), and terrestial red-bed deposits were formed as the seas fluctuated back and forth over the area. Marine conditions returned in Jurassic (135-180 m.y.B.P.) time, only to retreat at the end of the Jurassic period. A major marine invasion started in early Cretaceous time depositing thin sandstone, shales, and bentonites, creating reservoirs for biogenic gas. This continued until the start of the Laramide orogeny near the end of the Cretaceous period. The Tertiary period was a period of repeated uplift (Bowdoin Dome), accompanied by folding, thrusting, and high-angle faulting, and the deposition of thick terrestrial sediments in the intermountain basins (Williston Basin). The tectonic activity may have formed structural traps for hydrocarbon accumulation. Volcanism was active in mid to late Tertiary time. Thick volcanic deposits accumulated locally, and volcanic ash was distributed widely. This volcanic ash may have been a source rock of uranium; this uranium may have migrated by groundwater into favorable rock units in the area. The Quaternary (2-3 m.y.B.P.) period is noted for widespread glaciation; during this period, continental glaciers advanced beyond the present course of the Missouri River and retreated, leaving scattered morainal deposits consisting of sand and gravel.

3.0 ENERGY AND MINERAL RESOURCES

3.1 General

There is no known mineral production within the Bitter Creek GRA. The area has the potential, however, for the following resources: bentonite, uranium, natural gas, sand, and geothermal energy sources.

Figure 3.1, "Mineral Occurrence Map," illustrates the presence of any known past or present mine locations, or occurrences of mineral deposits and GEM resources within the GRA. Information for this figure came from the USGS' Computerized Resource Information Bank (CRIB), the USBM's Minerals Availability System (MILS), and the Petroleum Information (PI) Corporation's Dry Hole Maps.

3.2 Potential Resources

The Bearpaw Shale Formation contains significant bentonite resources in other areas of the state (Berg, 1969). Because this formation outcrops within the study area, it is expected that bentonite occurs within the WSA. Uranium anomalies in airborne radiometric data indicate that parts of the Bearpaw Shale may have accumulated significant levels of uranium (Geodata International, 1981). Scattered morainal sand and gravel deposits may occur within the WSA as upland deposits similar to those found south of the study area (Jensen and Varnes, 1964). Gas may occur in the study area primarily in stratigraphic traps similar to those found in the Bowdoin Dome area to the south (Rice et al., 1980).

3.3 Land Status

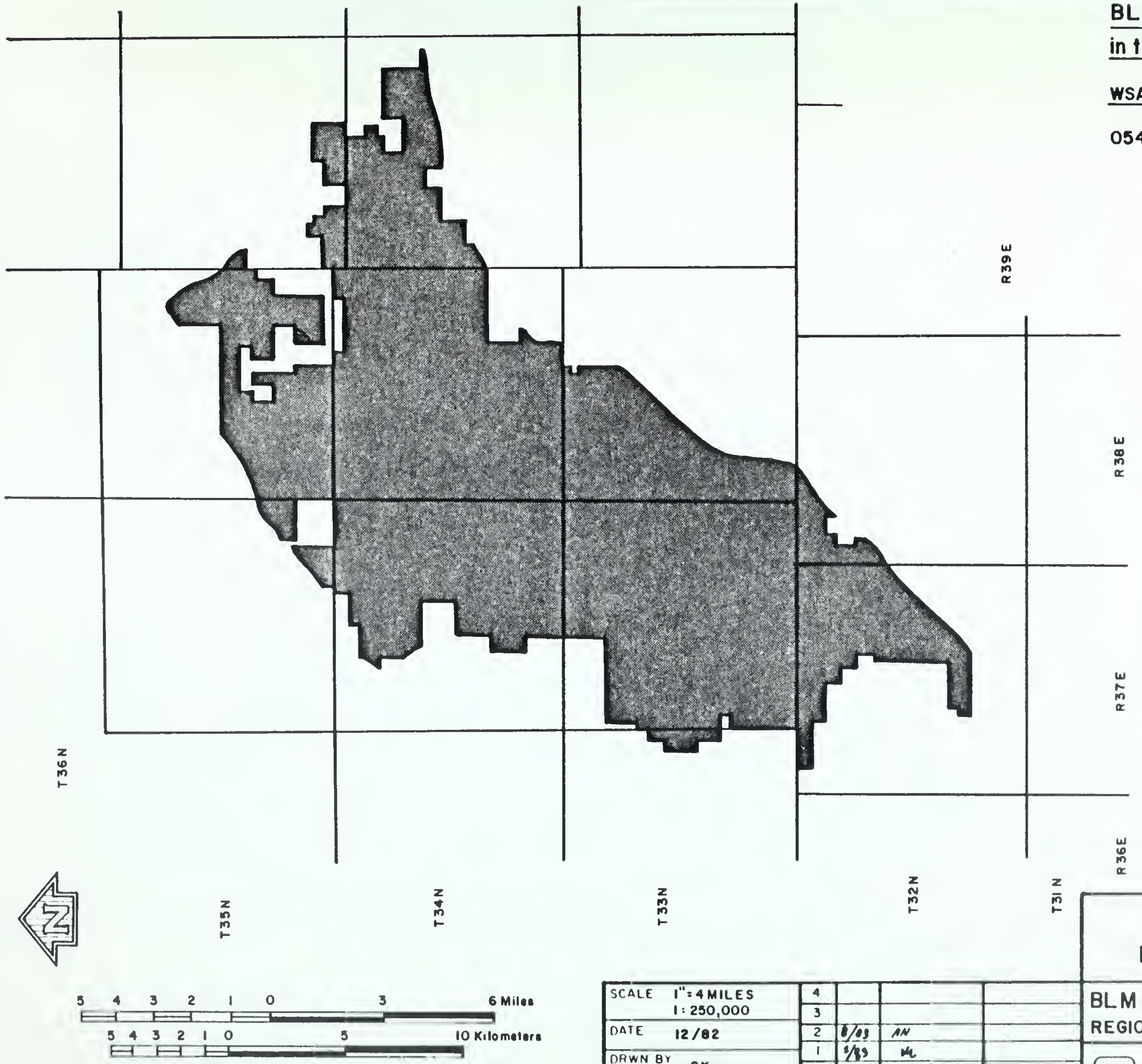
There are no patented or unpatented mining claims within the study area, but the GRA is blanketed with oil and gas leases. Figure 3.2, "Claim and Lease Map," illustrates the locations of any oil and gas leases, patented claims, or unpatented claims in the Bitter Creek GRA. As shown, there are no patented claims or unpatented claims in the Bitter Creek GRA.

3.4 Deposit Types

Bentonite was originally deposited as beds of volcanic ash during the region's marine environment (Berg, 1969); bentonite is now found interbedded with units of the Bearpaw Shale with which it was originally deposited.

BLM Wilderness Study Areas Included in the Bittercreek GRA

WSA	NAME	ACREAGE
054-356	Bittercreek	59,112



●	Oil Well
☼	Gas Well
✸	Oil & Gas Well
⚒	Mine
⚒	Inactive Mine
■	Ore Body
◧	Deposit
▨	Approximate Boundary of Wilderness Study Area

(USGS, 1982; USBM, 1982; PI, 1982)

Bittercreek GRA, Montana

MINERAL OCCURENCE MAP

SCALE	1" = 4 MILES 1:250,000
DATE	12/82
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APRVD	WL

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2	8/83	AN	
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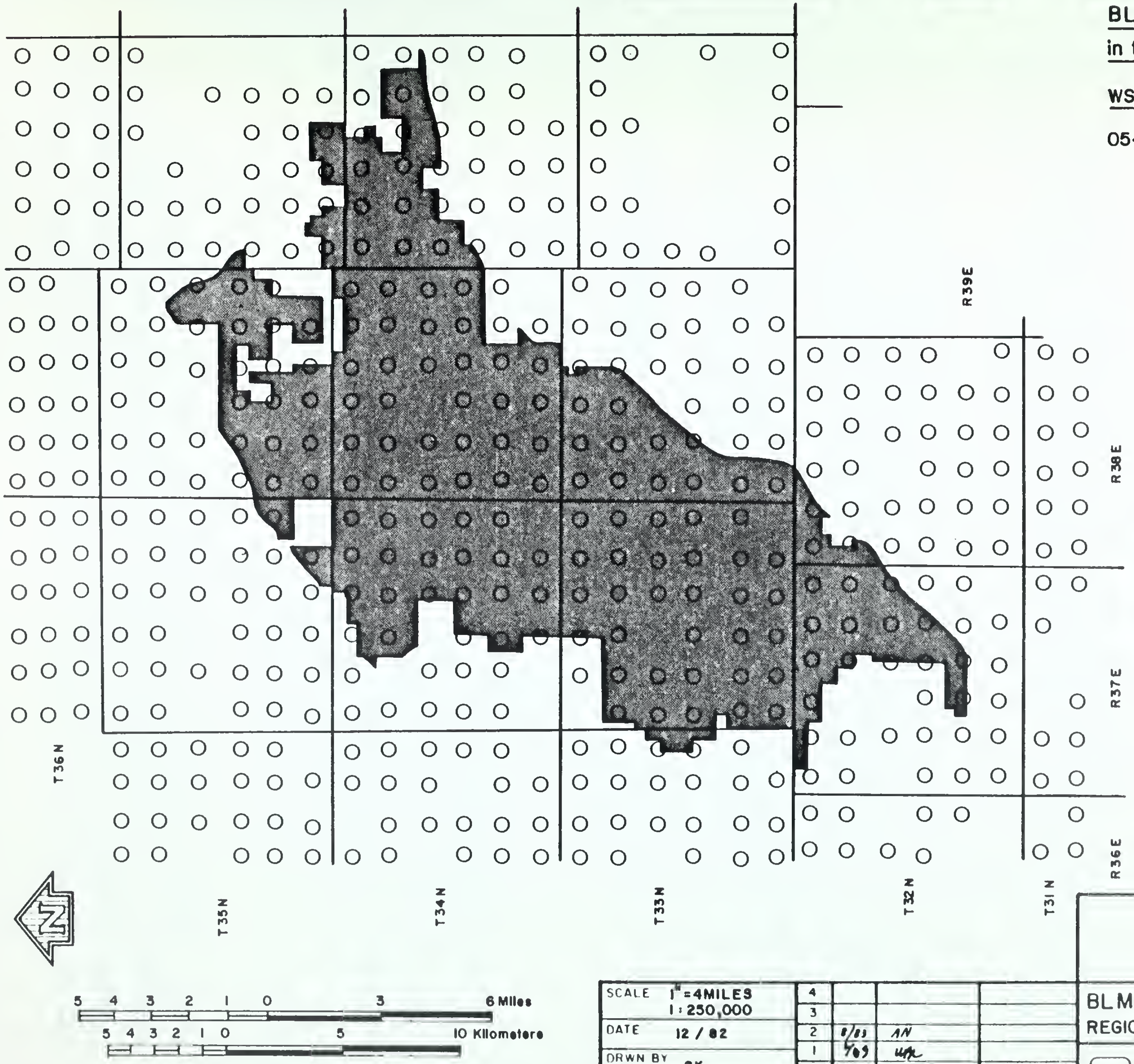
FIGURE 3.1



BLM Wilderness Study Areas Included in the Bittercreek GRA

WSA	NAME	ACREAGE
054-356	Bittercreek	59,112

○ Oil & Gas Lease

△ Patented Claim

X Unpatented Claim

▨ Approximate Boundary of Wilderness Study Area

NOTE: Symbols illustrate those sections where claims or leases are present

(BLM, 1982)

Bittercreek GRA, Montana

CLAIM and LEASE MAP

BLM GEM RESOURCES ASSESSMENT
REGION 6 WYOMING and MONTANA

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PASADENA, CALIFORNIA

FIGURE 3.2

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Gas has accumulated in thin sandstone stringers of the Colorado Shale of Upper Cretaceous age. Any upward migration of gas, from a generating zone, would be trapped in these sand stringers between impermeable bentonitic shales along the margins of the Bowdoin Dome south of the WSA (Rice et al., 1980). Information on gas potential within the WSA is sparse. A detailed examination of well logs would be needed to determine whether suitable horizons for the accumulation of gas exists.

Low temperature geothermal wells (1° x 100 feet gradient) within the area could supply space heating requirements from water in deep reservoirs; this development is unlikely, however, due to the high initial costs of such a project.

Glacial sand and gravel deposits may occur within the WSA because the area was covered by continental glaciation during Pleistocene time (Jensen and Varnes, 1964). Sand was carried from source areas northward by glaciers and was probably redistributed in part by aeolian processes as the glaciers retreated. Potential deposits are probably thin and scattered, and could only be used as local sand sources.

3.5 Resource Economics

3.5.1 Industrial Minerals

Major uses of bentonite are for drilling mud, iron ore pelletizing, and foundry sand bond. Prices for bentonite range from $2 to $200 per short ton, depending on type and quality. The total quantity of clays produced domestically decreased by 6 percent in 1981. The demand for clays is expected to increase at an annual rate between 2 and 4 percent through 1990.

3.5.2 Uranium

The current price of uranium (approximately $17 per pound in October, 1982) is low enough to discourage additional mining and exploration. A turnaround in national nuclear policy will be necessary to return the industry to profitability. Reserves far exceed demand at present and numerous mines with

significant measured reserves of U_3O_8 have closed due to the low demand for uranium and high production costs. When and if nuclear policy and attitudes change, the uranium industry will recover slowly but probably not to the extent of the 1970s.

3.5.3 Gas

The economics of any gas resources which might be found in the study area is dependent on pressures, volumes, and BTU content. Based on the geology and history of gas development in north central Montana, gas reservoirs in the study area can be expected to be of low pressure and low volume. If gas reservoirs of ample volume can be established in the area, a market for this resource would appear to be available through the pipeline system now serving the Bowdoin Dome gas field.

3.5.4 Geothermal

Water temperatures of 42°C at 975 meters (107°F at 3,200 feet) in wells drilled for oil and gas on Bowdoin Dome suggest a geothermal resource that can be used for space heating. However, due to large initial costs for development and low population density in the region, coal and gas which are relatively cheaper will continue to be the primary heating fuels.

4.0 LAND CLASSIFICATION FOR GEM RESOURCE POTENTIAL

4.1 General

The Bitter Creek WSA is considered potentially favorable for occurrences of the following GEM resources: bentonite, sand, uranium, natural gas and geothermal resources. The known geologic environment and the inferred geologic processes in the study area do not indicate a favorable environment for the accumulation of other GEM resources.

In order to better evaluate the occurrence or potential occurrence of resources in the GRA, a 2-part resource classification scheme has been adopted

as requested by contract. Each resource or potential resource within the GRA will receive an alpha-numeric classification. The number designation will range from 1 to 4, and will indicate the favorability of the geologic environment, geologic processes, and mineral occurrences for the presence of a particular resource or group of resources. The letter designation will range from A to D, and will indicate the level of confidence to be associated with the numerical designation. Figure 4.1, "Land Classification Map," illustrates the areas of potential GEM resources with their assigned classifications for the WSA within the Bitter Creek GRA. Figure 4.2, "Resource Classification Scheme," provides a detailed description of the number and letter designations used in the resource classification scheme.

4.2 Industrial Minerals

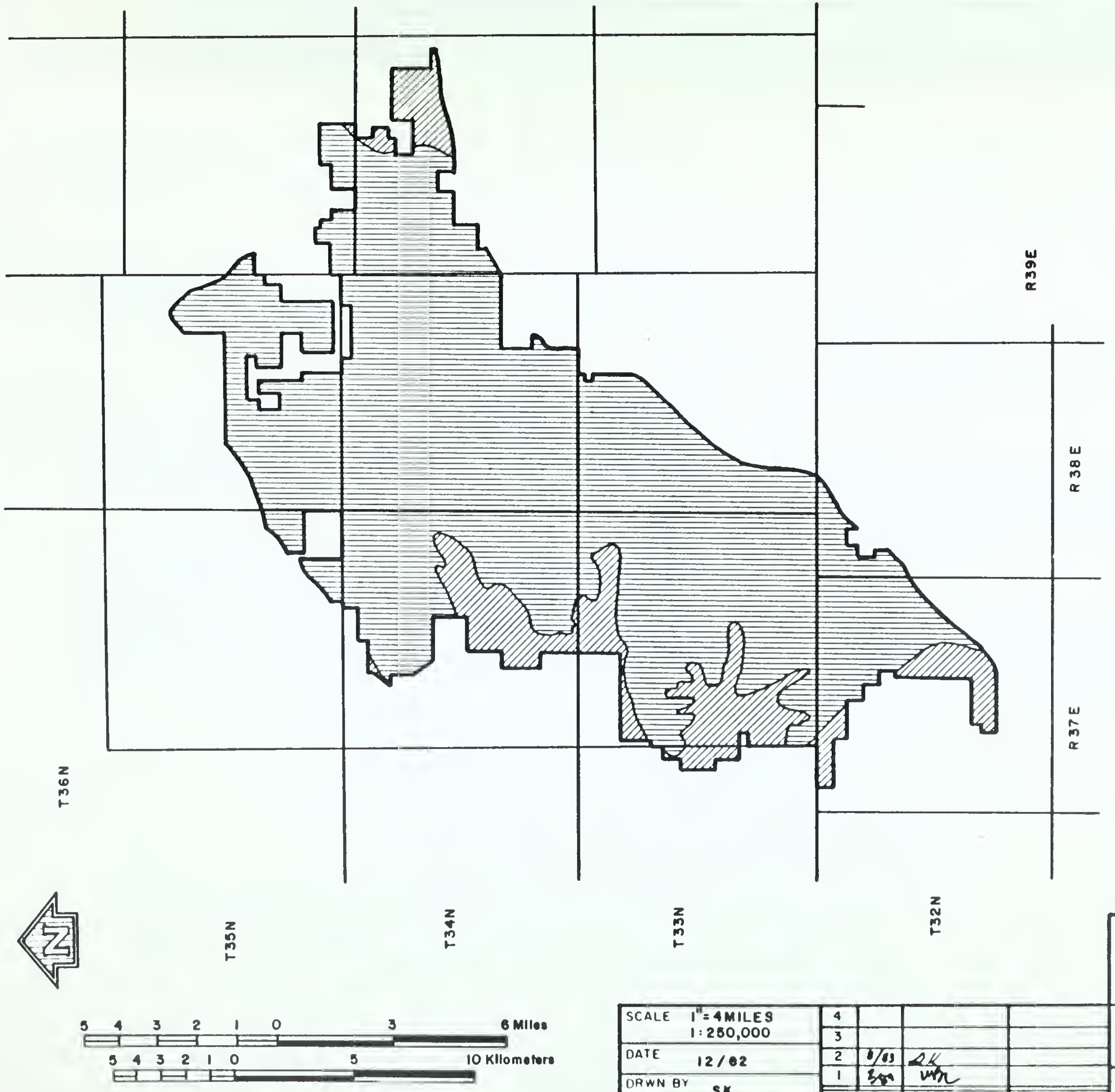
The Bitter Creek WSA is considered to have a moderate favorability for the potential occurrence of bentonite in areas of the Bearpaw Shale based on direct but quantitatively minimal evidence (classified 3C) (Berg, 1969). This classification is based upon the abundance of bentonite in the Bearpaw Shale which crops out in the WSA (International Exploration, 1980). The potential occurrence of sand and gravel in the study area is classified as 2B; this classification is based on glacial and fluviatile processes known to have been active in the area (Jensen and Varnes, 1964).

4.3 Uranium

The Bitter Creek WSA is considered to have a low favorability for the potential occurrence of uranium based on indirect evidence (classified 2B). This classification is based upon airborne uranium anomalies within the Bearpaw Shale in adjacent areas (Geodata International, Inc., 1981).

4.4 Gas

The Bitter Creek WSA is considered to have a high favorability for the potential occurrence of gas based on abundant direct and indirect evidence (classified 4D). This classification is based upon the nearby production of



BLM Wilderness Study Areas Included in the Bittercreek GRA

WSA	NAME	ACREAGE
054-356	Bittercreek	59,112

SYMBOL	GEM RESOURCE	CLASSIFICATION
▥	Uranium Bentonite Gas Geothermal Sand and Gravel Other GEM Resources	2B 3C 4D 2D 2B 2C
▨	Gas Geothermal Sand and Gravel Other GEM Resources	4D 2D 2B 2C
☐	Approximate Boundary of Wilderness Study Area	

Bittercreek GRA, Montana

LAND CLASSIFICATION MAP

BLM GEM RESOURCES ASSESSMENT
REGION 6 WYOMING and MONTANA

TETRA TECH INC
PASADENA, CALIFORNIA

FIGURE 4.1

SCALE	1"=4MILES 1:250,000
DATE	12/82
DRWN BY	SK
APRVD	WL

	DATE	DRWN BY	APRVD
4			
3			
2	8/83	sk	
1	3/83	wh	

REVISIONS

Numerical Classification Scheme

1) The geologic environment and the inferred geologic processes do not indicate favorability for accumulation of mineral resources.

2) The geologic environment and the inferred geologic processes indicate low favorability for accumulation of mineral resources.

3) The geologic environment, the inferred geologic processes, and the reported mineral occurrences indicate moderate favorability for accumulation of mineral resources.

4) The geologic environment, the inferred geologic processes, the reported mineral occurrences, and the known mines or deposits indicate high favorability for accumulation of mineral resources.

Letter Classification Scheme (Level of Confidence)

A) The available data are either insufficient and/or cannot be considered as direct evidence to support or refute the possible existence of mineral resources within the respective area.

B) The available data provide indirect evidence to support or refute the possible existence of mineral resources.

C) The available data provide direct evidence, but are quantitatively minimal to support or refute the possible existence of mineral resources.

D) The available data provide abundant direct and indirect evidence to support or refute the possible existence of mineral resources.

Figure 4.2 Resource Classification Scheme

gas identified within the Bowdoin Dome area to the south and potentially favorable stratigraphic horizons underlying the WSA (Rice et al., 1980).

4.5 Geothermal

The Bitter Creek WSA is considered to have a low favorability for the potential occurrence of geothermal energy sources based on abundant direct evidence (classified 2D). This classification is based upon the potential for low temperature thermal waters (normal geothermal gadients) associated with deep reservoirs in the Bowdoin Dome.

4.6 Other Gem Resources

There exists quantitatively minimal direct evidence to support a low favorability classification for the potential occurrence of other GEM resources in the WSA (classified 2C). This classification is based on the geologic environment and inferred geologic processes that have been identified within the WSA.

5.0 RECOMMENDATIONS FOR FURTHER WORK

5.1 Work Recommended to Complete Data Base

A number of investigations could be implemented to generate additional data to supplement the conclusions of this phase I report for the Bitter Creek GRA. Since the geology of the area is poorly known, it is recommended that an aerial photogeologic mapping study with some field checking be performed to verify the preliminary geologic information. Oil well logs should also be examined to determine if suitable stratigraphic horizons exist for the accumulation of gas.

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